METEOROLOGICAL OFFICE
13 JUN 1978
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Agricultural Memorandum No. 833

Viticulture: the effects of surface slope on direct radiation.

Introduction

In Germany, permission to plant new vineyards is given only if local climatic conditions guarantee the production of grape juice of a quality exceeding the minimum allowed for that particular wine growing area.

With several thousand enquiries each year it is impossible for the agro-meteorologist to survey more than a few of the projected sites. As a result a considerable reliance is placed on the estimated direct solar radiation which will be received at a site in assessing its suitability, since only the direct component of the global radiation can be enhanced by the site's slope and orientation. (Brandtner 1975).

Estimates have now been made of direct solar radiation for sloping sites in southern England. The season of interest has been taken as April to October, and over this period the direct radiation comprises about half the global radiation. It is assumed as a reasonable approximation that the diffuse radiation is independent of the surface's slope and orientation.

Calculations

The basic equation is

$$\sin\gamma = (\sin\phi.\cos\nu - \cos\phi.\sin\nu.\cos\alpha)\sin\delta + (\cos\phi.\cos\nu + \sin\phi.\sin\nu.\cos\alpha)\cos\delta.\cos\tau + (\sin\nu.\sin\alpha.\cos\delta.\sin\tau)$$

(Brandtner 1975)

where γ is the angle between the perpendicular to the surface and the solar beam
ϕ is the latitude
ν is the slope of the surface
α is the fall-line of the slope (west = 90°, S = 0°, E = −90°)
δ is the solar declination = $23.5 \cos 2\pi \frac{(d - 173)}{365}$
d = day of year (1 Jan ≡ 1)
$\tau = \pi/12\ (t - 12)$

The equation was integrated to give

$$\int_{t_1}^{t_2} \sin\gamma\, dt = (\sin\phi.\cos\nu - \cos\phi.\sin\nu.\cos\alpha)\sin\delta\,(t_2 - t_1)$$
$$+ \frac{12}{\pi}(\cos\phi.\cos\nu + \sin\phi.\sin\nu.\cos\alpha)\cos\delta\left[\sin\tfrac{\pi}{12}(t-12)\right]_{t_1}^{t_2}$$
$$- \frac{12}{\pi}(\sin\nu.\sin\alpha.\cos\delta)\left[\cos\tfrac{\pi}{12}(t-12)\right]_{t_1}^{t_2}$$

where t_1 is the time of sunrise $\simeq \frac{12}{\pi} \arccos(\tan\delta . \tan\phi)$

t_2 is the time of sunset $\simeq (24 - t_1)$

$\int \sin\gamma$ was calculated for a particular slope $(= \int \sin\gamma_S)$
and for the horizontal surface $(= \int \sin\gamma_H)$

The ratio $\int \sin\gamma_S / \int \sin\gamma_H$ represents the enhancement of direct solar radiation on clear days due to surface slope.

Table I gives an example of the ratios, averaged over the month of May.

If the diurnal variations of cloud are ignored, the ratio allows the calculation of direct solar radiation on sloping surfaces from the measurements of radiation falling on horizontal surfaces, or from estimates of the latter based on the measured duration of bright sunshine.

Ten-year (1966–1975) averages of monthly totals of direct radiation at Kew were used to derive a relation between average daily totals of direct radiation on a horizontal surface ($\bar{I}$) and the extra-terrestrial global radiation $\bar{G}o$ (averaged over one month).

$$\bar{I}/\bar{G}o = 0.5\ \bar{n}/\bar{N} \qquad \text{(Cowley 1978)}$$

where $\bar{n}$ is the average daily bright sunshine and
$\bar{N}$ is the average day length for the month.

The relation includes a correction for the application to rural sites (the regression coefficient for Kew was 0.465). The equation was used to estimate monthly average values of direct solar radiation on a horizontal surface at Littlehampton (50° 48'N, 5 m above sea level), using 20 year averages of measured sunshine figures (Table II).

The enhancement of the April – October total which was produced by a slope of 10 degrees orientated at 190 degrees (similar to the situation of a nearby vineyard) was from 440 kw hr. m^{-2} to 473 kw hr. m^{-2} or about 7.6%.

Discussion

Brandtner showed that the optimum slope for the postulated growing season was about 28 degrees, facing south (at 50 degrees north). At Littlehampton this would then give a seasonal total for direct radiation of about 498 kw hr. m^{-2}, or an increase of 13.3%, from that incident on a horizontal surface.

Brandtner also gave season totals of direct radiation on a horizontal surface in the Rheinhesse district (at about 49.7°N and 90 m above sea level) of 391 to 405 kw hr. m^{-2}, some 8 to 11% below the corresponding estimates for Littlehampton.

He commented that the average cloudiness in the immediate vicinity of the Rhine (eg the first site) is higher than that for some adjacent areas (eg the second site).

Comparing average sunshine totals for April – October for the south of England with the area around Rheinhesse, it would appear that the German totals are about 6% higher than those in England. This would at first sight appear to indicate a higher receipt of solar radiation.

However the aerosol content of the air if sufficiently large will attenuate strongly the direct solar beam. It is likely that the summer aerosol content over continental Europe is larger than that in the more maritime air masses which affect southern England. The fractional attenuation of direct radiation by aerosol is

$$f = 1 - \exp(-\tau_a \sec z)$$

where z is the solar zenith angle, and τ_a is the attenuation coefficient (Unsworth and Monteith 1972). The average value for τ_a for Kew over the growing season, weighted according to the monthly radiation totals, is about 0.4, which in the absence of cloud would produce a reduction of about 50% in direct radiation from the value for a completely transparent atmosphere. The clearer air at Littlehampton would lead to a value for τ_a smaller than 0.4. A value of τ_a over the two areas in Rheinhesse about 0.1 larger than that for Littlehampton would be sufficient to produce the lower radiation totals at the German sites.

The success of viticulture in this region of Germany is the result therefore of high temperatures during the growing season caused by the continental summer climate, rather than high solar radiation on the vineyards.

A value of around 1000 degree days above the base of 10°C over the six month period May - October is usually taken as the lower limit for successful viticulture abroad, Cochrane (1974) suggests that the values in southern England are nearer 750 degree days, so an increase in the mean daily temperature of greater than 1°C would be required to achieve the accepted criterion.

Clearly the success of viticulture in England depends on different commercial factors than those common to the main wine-producing countries: for example much English wine is sold "at the farm gate" at high prices.

Increasing vineyard acreage in England are likely to saturate this type of market eventually, and so it is important that new ventures operate at lower than the present average cost in order to assure commercial viability. Selection of a site with slope and orientation which maximise the incident radiation may become increasingly important in assuring a successful enterprise.

Any comments or criticisms should be sent directly to the authors.

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April 1978

REFERENCES

BRANDTNER, E.	1975	'The Climatology of the Wine Growing Areas', translated from Agrometeorology Today
COCHRANE, J.	1974	'Meteorological observations in Hambledon Vineyard in 1972' Weather 29 No 4 144-147.
COWLEY, J.P.	1978	Personal communication.
UNSWORTH, M.H. and MONTEITH, J.L.	1972	'Aerosol and solar radiation in Britain' Quart. J. R. Met. Soc., 98 778-797.

TABLE I

FRACTIONAL CHANGE IN INTENSITY OF SOLAR RADIATION
INCIDENT ON SLOPES OF VARIOUS EXPOSURES

MAY 50 DEGREES NORTH

AZIMUTH

SLOPE	140	150	160	170	180	190	200	210	220	DEGREES
5	1.013	1.015	1.016	1.017	1.018	1.017	1.016	1.015	1.013	
10	1.018	1.022	1.025	1.027	1.028	1.027	1.025	1.022	1.018	
15	1.015	1.021	1.026	1.029	1.030	1.029	1.026	1.021	1.015	
20	1.004	1.013	1.019	1.023	1.024	1.023	1.019	1.013	1.004	
25	0.986	0.996	1.004	1.009	1.010	1.009	1.004	0.996	0.986	
30	0.960	0.973	0.982	0.987	0.989	0.987	0.982	0.973	0.960	
35	0.927	0.941	0.952	0.958	0.960	0.958	0.952	0.941	0.927	
40	0.887	0.903	0.915	0.922	0.924	0.922	0.915	0.903	0.887	
45	0.840	0.858	0.871	0.879	0.881	0.879	0.871	0.858	0.840	
50	0.787	0.806	0.820	0.829	0.831	0.829	0.820	0.806	0.787	

MAY 51 DEGREES NORTH

AZIMUTH

SLOPE	140	150	160	170	180	190	200	210	220	DEGREES
5	1.013	1.016	1.017	1.018	1.019	1.018	1.017	1.016	1.013	
10	1.019	1.023	1.027	1.029	1.029	1.029	1.027	1.023	1.019	
15	1.017	1.024	1.028	1.031	1.032	1.031	1.028	1.024	1.017	
20	1.007	1.016	1.022	1.026	1.028	1.026	1.022	1.016	1.007	
25	0.990	1.000	1.008	1.013	1.015	1.013	1.008	1.000	0.990	
30	0.964	0.977	0.987	0.993	0.995	0.993	0.987	0.977	0.964	
35	0.932	0.947	0.958	0.964	0.967	0.964	0.958	0.947	0.932	
40	0.893	0.909	0.921	0.929	0.931	0.929	0.921	0.909	0.893	
45	0.846	0.865	0.878	0.886	0.889	0.886	0.878	0.865	0.846	
50	0.794	0.813	0.828	0.837	0.840	0.837	0.828	0.813	0.794	

MAY 52 DEGREES NORTH

AZIMUTH

SLOPE	140	150	160	170	180	190	200	210	220	DEGREES
5	1.014	1.016	1.018	1.019	1.019	1.019	1.018	1.016	1.014	
10	1.020	1.025	1.028	1.031	1.031	1.031	1.028	1.025	1.020	
15	1.019	1.026	1.031	1.034	1.035	1.034	1.031	1.026	1.019	
20	1.010	1.019	1.026	1.030	1.031	1.030	1.026	1.019	1.010	
25	0.993	1.004	1.012	1.018	1.019	1.018	1.012	1.004	0.993	
30	0.968	0.982	0.992	0.998	1.000	0.998	0.992	0.982	0.968	
35	0.937	0.952	0.963	0.970	0.973	0.970	0.963	0.952	0.937	
40	0.898	0.915	0.928	0.935	0.938	0.935	0.928	0.915	0.898	
45	0.852	0.871	0.885	0.893	0.896	0.893	0.885	0.871	0.852	
50	0.800	0.820	0.835	0.845	0.848	0.845	0.835	0.820	0.800	

TABLE II

Monthly averages of direct solar radiation on horizontal and sloping surfaces for Littlehampton (20 year means).

	monthly total kw hr./m^2 (horizontal)	Factor for 51°N 10°/190°	Resulting value for the sloping site
April	52.0	1.104	57.4
May	77.2	1.029	79.4
June	83.5	0.997	83.2
July	76.4	1.010	77.2
August	66.9	1.068	71.5
September	47.6	1.172	55.8
October	36.0	1.345	48.4
Total Apr–Oct	439.6 kw hr/m^2		472.9 kw hr/m^2